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ABSTRACT

The characteristics and major events of early American science are discussed in this paper. The philosophical influences and scientific practices of prominent scientists in early American time periods are examined and referenced in terms of their orientation to inquiry-oriented methods. Specific descriptions of the scientific accomplishments of Benjamin Silliman, Louis Agassiz, and Asa Gray are offered. The conditions and academic emphases found in higher education instructions and in secondary schools prior to and during the early 1900's are also highlighted. This historical review suggests that 19th century and early 20th century science was not conducive to planned inquiry, especially at higher levels of sophistication, and that in all probability lower levels of inquiry were accidental strategies in some 19th century American classrooms. Parallels are presented between the progression of science and the history of the teaching of science. (ML)

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AN EXAMINATION OF POSSIBLE ORIGINS
OF INQUIRY INSTRUCTION IN SCIENCE

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Early American Science

Although American science probably began after the conclusion of the War of 1812, there was some science activity in the new colonies prior to that time. Teaching science prior to and immediately after this presumed advent of American science left much to be desired in terms of current understanding of inquiry and experimentation. The forerunners of Copernicus, Galileo, and Vesalius, as Conant stated, "passed on facts and methods but not the spirit of scientific investigation."^[3]

Scientific inquiry and experimentation as understood currently were even resisted by most practicing scientists for philosophical reasons until the mid-1800's. Instead, faith was at least as important as empirical data and in many instances it dominated the practice of science. This faith was often a complex mixture of Christian theology, idealism and entrenched traditions. It also was a condition that had its roots in many centuries of disagreements between the Church and the practices of science.

Most of the practicing scientists responsible for significant discoveries were also men with strong Christian convictions. This especially was true in America where many of the gentlemen-amateur scientists were ministers of religion. Much energy was devoted to establishing science as a respected field of study at a time when theology was the most powerful discipline.

Even tradition had theological overtones as exemplified by the philosophical dominance of Bacon's and Newton's approach to scientific investigation. Baconian philosophy dominated early American science, and the gathering of facts for inductive generalizing was the prime mode of inquiry. It was assumed that error could not possibly arise in the observation of facts and

high order classification was seen as perhaps the ultimate in achievement. Botanical taxonomy was considered the model for Baconian methodology and it was within this context of science that Americans excelled in this early period of our scientific history.

The greatest merit of Bacon's thinking has been suggested to be "his insistence upon a gradual passage from concrete facts to broader and broader generalization."^[2]

An excellent example of science practiced in the early 1800's that models Baconian principles is reported by Daniels when he discusses the investigation of magnetic lines by Loomis. In one of the first large-scale investigations, Loomis engaged others in collecting data about magnetic lines and organized the data and drew maps. At no time did he attempt to discuss why variations occurred in different locations, and when dissatisfaction with this treatment of data prompted Lathrop to "hypothesize" regarding the differences, his published suggestions were ignored everywhere. Loomis continued to believe that he could determine an indisputable law if only he could gather more complete information (facts).^[4]

This philosophy about how science functions was openly challenged around 1830 but remained persistent and dominant for several additional decades and surfaced in full force during the debates about evolution and uniformitarianism in the mid-1800's. Even in the field of medicine, there was a reluctance to hypothesize though some 200 kinds of different disease had been identified with no real understanding of the cause of disease. Such was the thinking during the birth and infancy of science in America.

In view of these circumstances, it takes no intuitive leaps to assume that inquiry oriented science did not exist in classrooms.

In the mid-1800's there was an American indifference to basic research, but much effort was devoted to applied science. In North American Review, 1852, David Wells commented "the Yankees are unparalleled in this respect among all nations of the earth, both past and present." [1]

This attention to applied science, however, was not shared by many scientists who resented what they considered an overemphasis on applications of science and pressure to worship at the shrine of utility.

It was also during this period that the American Association for the Advancement of Science (AAAS) was organized in 1847. This organization was planned in Boston during the 1842 conference of the American Association of Geologists and Naturalists (AAGN), a group that essentially was transformed into AAAS. Forty members were present at the Boston meeting which heard Benjamin Silliman's presidential address delivered to almost 500 persons. Charles Lyell, who was touring the United States, also met with the group and probably was a major attraction.

The American Association for the Advancement of Education (AAAE), founded in 1850, established a close relationship with AAAS and both joined in promoting the idea of a national university and a school for advanced training in science. Goals of curricular reform and research programs proved premature and led to the dissolving of the AAAEd, but precollege teachers entered this void and formed the National Education Association (NEA) in 1857. Struggling for recognition, new and more uniform curricula, and a positive attitude toward basic research undoubtedly provided little opportunity for a revolution in instructional strategy. It was not a time for inquiry as a methodology to surface in any sophisticated form.

America Becomes Independent

From the end of the colonial period up to the Civil War, there were changes in curriculum, in attitudes about who should go to school, and even in the nature and understanding of science, but it is doubtful that teaching practices radically changed. Certainly nothing comparable to the radical departure from Baconian science could be identified in school practices, although the democratization of American education, a revolution of enormous magnitude was born during this period. Perhaps it is not even appropriate to look for science teaching changes at this time because science itself was struggling for recognition as a valuable discipline.

The struggle of science for freedom from European dominance was being won and even nourished to some extent for political purposes. Tassel and Hall discussed the early 1800's in America as:

"a unique culture, a frustrated ambivalence: a distrust of products of the older monarchies, and on the other hand, a desperate desire for recognition in Europe."^[13]

This desire of Americans to be accepted as successful in creative scholarship and receive recognition from European contemporaries demanded publications and an interest in research. To accomplish this goal, there was an unavoidable pressure exerted toward more abstract investigation. The puritan antagonism for idle speculation had to subside.

If our researchers were struggling to make an adjustment, it should follow that such "idle speculation" was not likely to be found in the science classroom during this period.

Perhaps the most appropriate way to observe changes in science teaching is to do so through a look at college teaching. Without organized curricular development, college teaching is more likely to produce innovations through

efforts of individuals. It should also be quickly noted that science growth during the early part of the Nineteenth Century was more influenced by lyceums than by universities. A desire to train persons in practical science, however, did begin a trend to develop schools such as the Franklin Institute in Philadelphia, Rensselaer School in Troy, New York, and influenced practices at Harvard and Yale.

Amos Eaton hired a boat and took students out on Lake Erie for six weeks during summers for study and field work. Student participation was advertised by Rensselaer in 1826.^[13] Joseph Henry, who later became the first secretary of the Smithsonian, invented lecture-demonstration devices for physics and taught others how to use them. He collected and read student notebooks each week.^[13] As indicated, teaching methods were integrated in individual people rather than groups or movements. Therefore, an attempt will be made to view the changing nature of science and science teaching through the lives of three significant early American scientists.

Benjamin Silliman, 1779-1864, was the son of a highly respected minister and developed Yale's first chemistry lab.

Silliman, who is also credited with teaching the first course in geology in this country, prepared lectures with great care and often rehearsed demonstrations. He believed that "speaking to the mind through the eye" was an excellent way of imparting knowledge.^[8] He often illustrated presentations with five-foot square pictures which he funded through lectures outside the university. He became better known as an outstanding teacher and publisher than a contributing scientist.

Louis Agassiz, 1807-1873, educated and trained in Switzerland, probably did more to advance early American science than any other individual. He was

a complex mixture of charm, energy, intelligence, scientific expertise, and strong religious beliefs. Although primarily a zoologist, his greatest single accomplishment was his early work on glacial theory. Charles Darwin wrote to say, "I have enjoyed reading your work on glaciers, which has filled me with admiration," and also indicated that Buckland and Lyell had adopted Agassiz's theory in toto.^[12]

Agassiz was able to compromise idealism and empiricism without apparent conflict, for he firmly believed his task to be the discovery of the manner in which individual life forms demonstrated the act of creation by God and revealed the Creator's plan. His science was greatly influenced by his religious faith, but paradoxically he firmly believed that the scientist had to describe the facts as he knew them without reference to religious conviction or prejudice. His view on the plural origin of man was resisted by fundamentalists and what Darwin and Gray considered his metaphysical interpretation of some data was perplexing to them. His meticulous study and profound knowledge made him a formidable opponent. In 1854, Hooker wrote to Asa Gray from England, "I seldom see a zoological paper from North America without observing the impress of Agassiz's doctrine--another proof of how great a man he is."^[9]

Louis Agassiz was also an innovative educator who spoke forcefully for a national program of education, and was a leader of the Scientific Lazzaroni, a group of the best young scientists who united to improve American science. He was the dominant spirit in the Lawrence Scientific School at Harvard, a unit he managed to keep semi-autonomous.

As a teacher, Agassiz invited students to visit his lab, let them study specimens firsthand, and thereby gain direct knowledge. He directed field

trips to the countryside and seashore, encouraged students to make their own collections, and conducted instruction by correspondence with specimen collectors around the country. On one occasion, he handed over 1,000 specimens to a group of students, instructed them to separate the specimens into species, and absented himself for a week. After reviewing their work, he informed the students that they had made a significant contribution, thus exemplifying the conditions which prompted intense loyalty from his students and contributors. Agassiz's brand of teaching was a blend of Pestalozzi's object lessons, discovery learning, and active involvement. Students gathered and interpreted data and also assisted Agassiz in establishing a museum at Harvard. Within the content of a taxonomic system which dominated science and a Baconian philosophy which was even supported by Andrew Jackson, students did actively engage in science. Agassiz's methods were more similar to a European school with a professor and apprentices than an American school.

Asa Gray, 1810-1888, a contemporary of Agassiz's at Lawrence, was educated in America and more influenced by British empiricism than Agassiz's new German idealism. Although a devout Christian, Gray's religion was rational, and he became the first citizen of Darwinism in America. Darwin himself complimented Gray as being one of a few men who kept his book from being "a mere flash in the pan."^[6] He was also named the first professor of botany by Michigan regents in 1838, taught at Harvard in 1847, and was accepted as a peer by Hooker on his trip to Europe in 1855.

Hooker, Lyell, and Darwin applauded Gray's efforts to reduce the conflict between evolution and religious views when he argued that evolutionary theory did not speculate about the universe or its relation to ultimate moral law. Gray was thus cast between the two protagonists groups and had

difficulty satisfying either. Gray's debating won a victory for empiricism over idealism in American biology, but the debate led to fierce alignments on both sides, leading to choosing between science and religion. By 1860, Huxley's agnosticism became the banner carried for science and Gray's compromise satisfied few on either side, least of all Agassiz.

Gray was far more creative as a scientist than as a teacher, but he did try to get his students to perceive botany as a whole related system. While at Harvard, his teaching was influenced by Agassiz and the required curricular recitations and exercises.

Science Advanced Through Individuals

In a review of the lives of Benjamin Silliman, Louis Agassiz, and Asa Gray, several generalizations can be made with caution.

During this general period between the early and late 1800's, American science had developed respect and Europeans acknowledged Agassiz and Gray as formidable men of science. Respect and interest for science in this country also grew and the lectures of Silliman were in great demand and the attendance for debates between Agassiz and Gray at the American Academy of Arts and Science in Boston produced intense interest. Perhaps more for political than scientific concerns, even the federal government became involved in supporting science. Science as discipline had achieved respected status but it was still struggling for significant recognition in the curriculum. Practical and political considerations probably produced more impetus than academic concerns.

Just as science was beginning to bloom in this country, Darwinian theory created new conflicts, elicited the umbrage of Agassiz himself, and eventually created an either-or choice between science and religion for many Americans

of learning. It was not the most opportune time for science progress in this country to face a debilitating intellectual war. It was true, however, that the gentleman-amateur was slowly giving way to a more prepared professional and specialization was increasing, both factors which presumably strengthened the position of science.

Science lectures, debates, and demonstrations were a popular means of entertainment, and Silliman, among others, was paid well for his engaging productions. This popularity probably influenced attitudes about science among influential persons and indirectly may have assisted the acceptance of science as appropriate for the school curriculum.

Full tax support for schools was not yet a reality and the scientist of this era, as exemplified by Silliman, Agassiz, and Gray, contributed their own funds and time for fund raising with extreme dedication. Silliman contributed funds from his lecture tours, Agassiz proved to be a superb fund raiser, and all three expended personal funds for trips and materials.

At a time when the classics still flourished and mental discipline was stressed, Silliman and Agassiz sought diligently to make learning a meaningful and practical experience. Silliman, somewhat like the early humanists, sought to entertain his audience, but he was also interested in their learning. His dedicated effort to bring Gibbs' Cabinet of minerals to Yale was an attempt to encourage laboratory experience and practical activity. Agassiz's extreme effort to establish a museum of specimens at Harvard was a precursor of lab-oriented science instruction as was his practice of inviting students into his lab.

Inquiry instruction for most students at any level during this era was rare at best and probably non-existent. Even in the environment of an engaging

teacher like Silliman, Yale was rather known for harshness and discipline, and Agassiz taught at Harvard which provided a learning experience Henry Adams described as an "autobiographical blank." He complimented Agassiz's lectures as the only teaching that appealed to his imagination. It was a time in which colleges lacked faculty, students, money, or a vision to progress. For example, 239 colleges in 1850 had an average faculty of seven and few desired to become universities.

Birth of a New Century: Professionals Replace Gentlemen-Amateurs

Only 15% of the 461 founders of AAAS were professional scientists when they elected William Redfield, a harness maker, as their first president in 1848. The first American-conferred Ph.D. was awarded in 1861 by Yale's Sheffield Science School and within the next forty years the gentleman-amateur gave way to the professional. Before the turn of the century, presidents White of Cornell, Gilman of Johns Hopkins, and Harper of the University of Chicago, began innovations that included graduate studies, fellowships, scholarships, and a demand for scholarly research and publications. This was a period when laboratory work became more prominent and science replaced the classics in curricular prominence. An early version of the brain-drain was being experienced as universities became worried that the majority of the brightest young men were going into science.

Science was being substituted for the language and literature of the old curriculum which was losing its dominance. Thomas Huxley, in 1881, criticized the old curriculum by saying that neither the discipline nor the subject matter of classical education was of much value to students of physical science, and that valuable time should not be spent on either.^[7] Asa Gray lived to

see most of these changes, but died before Albert A. Michelson became the first American to receive the Nobel Prize in 1892. It was in this decade that the doctorate became important as a symbol of professional competence.

Higher Education

One example of the quality of colleges and the science teaching they rendered just prior to 1900 may be gleaned from a review of Simon Flexner's early education which was somewhat erratic but not grossly atypical for his time. As an unsuccessful scholar, he became a school drop-out at age fourteen, attempted a trade, enrolled in a proprietary school in pharmacy, and worked for several years. He graduated with a bogus M.D. degree because of the inferior scholarship and teaching present at the university he attended. Although considered a colleague, he was more an apprentice at Johns Hopkins Hospital and learned by doing more than by attending classes. It also can be noted that he entered the University of Louisville Medical School without ever having completed high school. These events in Flexner's life exemplify the academic environment around the turn of the century: poor articulation between high school and college; some schools and colleges of inferior quality; bogus degrees, especially in professions; small faculties with low enrollments; and only a small percentage of young people completing high school. It was not the environment in which one would expect to identify many worthy examples of planned inquiry oriented instruction.

During the time Flexner was growing up in the 1870's and 1880's, there was a proliferation of unqualified institutions and programs which became an embarrassment to states and professional groups alike.

Secondary Schools

Just prior to and during the early 1900's, the confusion surrounding what a high school was and what its curriculum should be prompted the formation of the College Entrance Examination Board (CEEB). By 1910, twenty-five Eastern colleges required CEEB exams in several disciplines for use as admission criteria. The period just prior to the turn of the century marked significant efforts to distinguish between a high school and college, establish college and university entrance requirements, and to initiate efforts to protect the public against bogus institutions and credentials.

Within high school classrooms, mental discipline was a predominant rationale for learning science. The National Education Association appointed a Committee of Ten which recommended more laboratory work and less recitation and drawing in 1892, but in 1906, it was believed by committee members that little had been accomplished.^[5]

Similar to preceding decades, this period was not a time when inquiry, discovering, and experimentation were infused in courses of study in any significant way. Under influence of committees, faculty psychology, and a doctrine of formal discipline, instruction was formal and systematized in the early 1900's, and high school courses simply mimicked college courses.

Prior to and during the early 1900's, the Pestalozzian "object method" had gained prominence and did challenge the listening, note-taking, and recitation which was prevalent in schools. It has been speculated that the object method philosophy may have influenced and helped promote quantitative laboratory work in physics and chemistry.

Pestalozzian influence was believed to be apparent in Harvard's famous list of experiments and outline of topics in physics which first appeared in

1887, and in a similar list for chemistry made available in 1888. These lists, in addition to stimulating laboratory work, also became an additional influence for standardizing the science curriculum.

A Prologue

An attempt to assign the precise advent of the first example of inquiry, even for lower taxonomic levels, would be certain to offend those of a prior decade or perhaps even a prior century. Precisely identifying the time when "experiments" gave way to experimentation is equally difficult. Perhaps some solace can be obtained from Haberman's description of a legacy:

"Legacies are not neat. They do not begin and end with critical events or memorable dates; neither are they of discrete or equal duration...(they appear) on a broken front, in an overlapping manner, in time categories that are not mutually exclusive."^[10]

In all probability, lower levels of inquiry were accidental strategies in some 19th century American classrooms; perhaps in Agassiz's laboratory, on Eaton's boat, or at one of Silliman's lectures. This era, however, was not conducive to planned inquiry, especially at higher levels of sophistication.

Perhaps Curt Stern's description of Thomas Hunt Morgan's "Fly Room" in 1915 will help put things in perspective:

"When rain fell on the roof of Schermerborn Hall, a bucket had to be placed in the room to catch the water which leaked through the ceiling. The microscope lamps were ordinary light bulbs, shaded by metal sheets cut out of ordinary cans. During

the two years I worked in the inspiring spiritual atmosphere of the Fly Room, I never opened my desk drawer without looking away for a while to give the cockroaches a chance to run into the darkness."^[11]

If we consider how slowly science has progressed and the profound struggles it survived and then consider that the history of the teaching of science is infantile by comparison, perhaps we can muster the patience necessary to advance beyond Baconian-like interference.

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